

NASA Spinoff Highlights

The Value of Space Exploration

NASA spacecraft have paid visits to all of the planets in our Solar System except Pluto. Plans for missions in the near future include examining that distant planet, landing on an asteroid, and even returning samples of a comet and the rocks and soil of Mars. In years to come NASA will lead the way in venturing beyond our Solar System to probe the mysteries of interstellar space.

The investment America makes to undertake the innovative research necessary to create cutting-edge research for spacecraft and instruments, and deliver them to far flung destinations, provides huge returns in science, technology, educational outreach, and commercial spinoffs through an innovative program that benefits us in our everyday lives.

The NASA Technology Transfer Program encourages public use of its research developments (<http://nctn.hq.nasa.gov>). This pioneering program promotes the transfer of NASA research and space exploration technologies to the public and private sectors. (<http://nctn.hq.nasa.gov/division/Agenda/Contents.html>). The benefits of NASA technology to everyday life are wide ranging—from radiation blocking sunglasses, bar codes in our supermarkets, changing the way we use the internet, to advances in medical research, airline safety and firefighting techniques.

Understanding gained through NASA research and space exploration promotes more effective skills in a wide range of everyday technologies and aids in producing and processing many materials, including metals, semiconductors, polymers and glass. A great example is the area of semiconductors, which have contributed improved efficiency in the computer and electronic communications revolution and support today's information-driven society. We drive cars and fly airplanes that were designed using NASA computer software. We live in homes and work in office buildings that carry electricity through flat conductor cables that incorporate NASA technology.

American space research has paid off handsomely for our nation, especially considering that the total allocation for NASA is less than one penny for every dollar in the 1.5 trillion dollar Federal budget. The rewards in commercial spinoffs helping grow the American economy are many times the return on this investment.

NASA has an ongoing commitment to provide benefits to everyone. As explorers, pioneers and innovators, NASA scientists, technologists and engineers boldly expand the frontiers of air and space to inspire and serve America and benefit the quality of life on Earth. Take a look at some of the NASA breakthroughs that have become successful spinoffs over the years. They were all a result of responding to the demands of our mission, *“to do what no one has done before”*.

Be sure to check out these other web sites for additional information about NASA's Commercial Technology Mission and Spinoffs:

<http://nctn.hq.nasa.gov/success/index.html>

<http://www.nctn.hq.nasa.gov/innovation/index.html>

<http://techtrans.jpl.nasa.gov/success/success.html>

<http://www.sti.nasa.gov/tto/online.html>

NASA Spinoff Highlights

Communications

Space Communications

Communicating with spacecraft demands the ability to speak and listen accurately across the vast expanse of space under harsh conditions. Developing the capability to send and receive over these long distances required a long-term series of innovations leading to the development of deep space antennas, precision timing systems and data processing codes.

These leaps in technology made Earth-orbiting and planetary exploration missions possible. JPL - the Jet Propulsion Laboratory, a NASA facility in Pasadena, California - developed error-correcting codes for communicating with spacecraft by establishing Reed-Solomon error correcting codes. These codes are information added to a transmitted spacecraft computer word that allows mission controllers to determine if the word has been corrupted, and to correct it so that the original information can be obtained. This allows mission controllers to convert the weak signals from distant spacecraft into valuable scientific and engineering information.

These advanced error correction codes are perfectly suited for deep space applications, but they also have very important commercial applications. Error correction codes, to lessen noise, are utilized in direct satellite TV and the multi-billion dollar communications industry, including pioneer companies such as McCaw Cellular - now part of AT&T.

Lasers and Communications

Lasers drill, cut, melt materials and are employed during precision surgeries on the human eye. They can also be used to transmit communications signals. Many of the advanced uses of lasers were developed at JPL for optical communications over interplanetary distances. The precise signal capabilities of these instruments make them a valuable tool in communication improvement for future NASA deep space missions. Their compact size, efficiency and durability also make laser technology attractive for future space interferometers - a new breed of telescopes on NASA drawing boards. Laser-based optical communications are a major factor fueling the rapid expansion of technology in the computer-based communication arena, and elsewhere in the commercial market.

Micro-Gyroscope for Global Communications

Smaller than a shirt button, and jointly developed by JPL and Hughes Space and Communications Company, this new gyroscope is lighter, cheaper, higher performing and less complex than its conventional counterparts - while ruggedly designed for continuous space operation. Hughes will use microgyros in its fleet of communications satellites. Other applications potentially include most anything that moves.

Computers, Instruments & Electronics

Cordless Tools

On the moon, astronauts used specially developed, portable, battery-powered electric tools to drill into the lunar surface and take samples of the crust. The tools they used were direct predecessors to today's cordless, rechargeable power tools that have become so common in construction and for a variety of household tasks.

Bar Codes

Common bar codes, now used for pricing in supermarkets, are an advancement of technology originally developed for uses within NASA, such as maintaining a highly accurate inventory of millions of spacecraft parts.

Next Generation Imaging Sensor-Active Pixel Sensor (APS)

These new imaging sensors require one-hundredth the power, and are one-tenth the size of comparable technology their predecessors, making them ideal for meeting the NASA goal of providing future missions lighter-weight and lower-powered instruments.

Smaller, faster, cheaper works well for industry, where the APS has already found uses in the automotive and medical fields. The low power needs of APS allows the physician to track the onset of osteoporosis, or perform dental radiography, using less than one-hundredth the radiation dosage to the patient. Photobit, a spinoff company from JPL, continues to work on such applications as air bag sensors, rear vision systems, digital cameras, machine vision, toys and entertainment and back up collision avoidance.

Data Compression

Data compression techniques condense the large amounts of information transmitted from remote spacecraft into smaller pieces. This increases the speed of the information returned on interplanetary missions, and contributes to the more efficient functioning of earth-based networks like the internet.

NASA Structural Analysis Computer Software — NASTRAN

In the early years of the space program, it took thousands of worker-hours, over many months, to analyze and solve structural problems in the design of aircraft and space vehicles, using conventional mathematical methods. Today design engineers are able to scrutinize and resolve thousands of structural issues in a matter of hours using NASTRAN, an extremely sophisticated computer program developed at the Goddard Space Flight Center. This significantly reduces development time as it improves the results.

NASTRAN basically performs complex analyses during structural design, and predicts how various elements of the design will react to many different conditions of stress and strain. Quick and inexpensive, it minimizes trial-and-error in the design process and makes possible lighter, safer structures.

The power of NASTRAN has been harnessed by hundreds of industrial firms to tackle structural challenges in automotive, aircraft, chemical plant, oil refinery, rail vehicle and architectural

design. This elegant system is now considered to be the most significant advance in structural analysis of our era.

Health and Medical

Body Imaging

The high-tech art of Digital Signal Processing (DSP) was pioneered at the Jet Propulsion Laboratory in the mid-1960s, for use in the Apollo Lunar Landing Program. Designed to allow computer-enhancement of pictures of the moon, this technology became the basis for the Landsat Earth resources satellites, and subsequently has been incorporated into a broad range of Earthbound medical and diagnostic tools.

Physicians and engineers in the Department of Radiology at the University of Michigan Hospitals, have developed a method for combining the best features of MRI and CT scans, to increase the ability to discriminate one type of body tissue from another. These technologies stem from JPL Digital Signal Processing breakthroughs. One of their research tools is a computer program originally developed to distinguish Earth surface features in Landsat image processing. This program, called HICAP, can be used to distinguish between healthy and diseased tissue using body imaging.

Skin Damage Assessment

A critical factor in the successful treatment of serious burns is accurate measurement of burn depth. The application of NASA ultrasound technology, originally developed to detect microscopic flaws in aircraft and spacecraft materials, has led to the creation of an advanced instrument that provides an immediate assessment of burn damage. This knowledge improves patient treatment and may even save lives in serious burn cases.

In 1983, NASA's Langley Research Center initiated a project to address the need for precise measurement of burn depth. Langley developed a prototype instrument capable of identifying the level at which burned tissue ends and healthy tissue begins. The Langley system, called Supra Scanner, directs ultrasonic waves into the burned area. The difference in density between damaged and healthy tissue causes sound waves to reflect at the point of interface, allowing for an accurate measurement.

Computer Reader for the Blind

More than 20 years ago, Telesensory in Mountain View, California, produced a spinoff technology that enabled the blind and deaf-blind to read almost anything in print. Their initial device, called Optacon, is a combination of optical and electronic technology and incorporates research performed at Stanford Research Institute under the sponsorship of NASA's Ames Research Center.

Optacon, which can be used with virtually any alphabet or language, has provided a new level of independence for thousands of blind people in more than 70 countries. The company later introduced an even more exciting aid, a second-generation spinoff that not only provides access to printed words, but also to the electronic information available on most personal computers.

Ocular Screening System

In the United States today, thousands of young children have eye defects which, if not detected and treated in the early stages, could result in permanent blindness. Until recently, there was no nationwide ocular screening program for the young, because there was no fast, reliable, economical method. Now, however, a NASA-patented invention called Visiscreen-100 provides the means for wide-scale detection of vision problems.

Visiscreen was developed jointly by NASA's Marshall Space Flight Center and Dr. Howard Kerr, President of Medical Sciences Corporation (MSC), its exclusive manufacturer.

Low Vision Enhancement

While some spinoffs from space research can save lives, others seek to improve the way we live. Three-million Americans suffer from visual impairment known as "low vision" meaning they are not totally blind, but have a minimal degree of useful vision.

The condition cannot be corrected surgically or with traditional eyeglasses. However, technologies developed for computer processing of satellite images, and vision enhancement headsets designed for Space Station use, have brought new hope. The Low Vision Enhancement System (LVES) - a head-mounted video display worn like goggles - allows those with low vision to see their surroundings more clearly, enabling them to perform everyday activities like reading and watching TV.

Speech Aids

A deaf person, who is learning to speak, requires assistance to modulate the tone and volume of his speaking voice. Recognizing this need, Joseph A. Resnick, president of Dynamed Audio Inc., Natrona Heights, Pennsylvania, invented the Resnick Speech Teacher system to provide visual cues for speech improvement.

Many deaf people, for example, tend to speak in unusually high-pitched tones. When they speak into the Speech Teacher system, it electronically processes their voice. Indicators on the device corresponding to the subject's sounds, are compared with a display representing the optimum speech tone. The speaker then tries to adjust his tone to match the model.

Vehicle Controller

In 1972, a paraplegic named Tom Wertz saw Apollo astronauts driving a Lunar Rover with just one hand - using a T-bar. After test-driving a rover himself, he realized that if such technology could be adapted to automobiles, it would help handicapped people become more independent. NASA and the Department of Veterans Affairs liked the concept, and contracted with Johnson Engineering, of Boulder, Colorado, to implement Wertz' idea.

Roughly ten years after Wertz first witnessed the Lunar Rover in action, Johnson Engineering installed a prototype Unistik vehicle control in a Ford van. This two-axis joystick controls the vehicle's steering, brake, and accelerator pedal. It allows the driver to control the vehicle through small, low-force hand motions from any position.

The Unistik Controller was designed for C-5 quadriplegics, such as Wertz, who have spinal cord lesions at the fifth cervical vertebra. People with such severe injuries have very limited use of

their upper extremities; they are able to move their hand only a few inches to either side. The joystick is ideal because it has a very low control resistance.

Unistik driving is simple. Moving the stick forward accelerates the vehicle, to the rear slows it down, and left or right turns the steering wheel in the proper direction. Moving the joystick to the two o'clock position, for example, will yield an accelerating turn to the right. Another joystick controls turn signals and headlights. A push of a button deactivates the Unistik, returning the van to normal operation so both handicapped and able-bodied people can drive the same vehicle.

Robotic Arm for Surgery

Technology developed by Computer Motion Inc. under a Small Business Innovation Research contract, produced a robotic arm that assists surgeons in the operating room in surgical procedures. This arm takes over the job of a surgical assistant, holding and positioning the laparoscope used by the surgeon to see inside the patient through a small incision. Hundreds of minimally invasive heart valve surgeries have already been completed with robotic assistance.

Computer Motion Inc. has gone on to create robotic operating room control centers with voice control interfaces. This centralizes a surgeon's control of multiple robotic devices. Surgeons can directly maneuver these smart devices using either voice control or a hand-held touch-screen pendant. The equipment also provides the surgical team with video and voice feedback on the status of each robotic device.

The combination of human and robotic skills, made possible by these Computer Motion Inc. innovations, may some day be used to service satellites in space, monitor experiments on the Space Station, or assist in the servicing and inspection of Shuttle payloads.

Telltale Nitric Oxide Reveals Breast Cancer

The war against breast cancer has a new weapon, thanks to an advanced sensor developed at JPL. The QWIP (Quantum Well Infrared Photodetector) camera uses extremely sensitive infrared sensors to do non-invasive mammography. Qwips were developed at JPL for astrophysics and atmospheric research. In the past, these devices had to be cryrogenically cooled, making them heavy and power hungry. JPL has advanced the state of Qwip imaging such that they are now portable and do not require subzero cooling to achieve accurate sensitivity readings.

Early versions of the sensor showed potential applications, such as locating hot spots during fires and observing volcanoes. A refined spinoff device, using Qwip camera technology, has more subtle medical applications. Studies determined that cancer cells exude nitric oxide. This causes changes in blood flow in tissue surrounding cancer that can be detected by a Qwip sensor-based system created by OmniCorder Technologies in Stony Brook, N.Y. They developed a BioScan System to screen woman for breast cancer, and received clearance to market the system in December 1999.

The BioScan System is sensitive to temperature changes of less than .015 degree Celsius (.027 degree Fahrenheit) and has a speed of more than 200 frames per second. It causes no discomfort to the patient and uses no ionizing radiation.

CCD for Breast Biopsy

Space research is saving lives with the help of Hubble Space Telescope technology. Breast biopsies can be performed, with a needle instead of a scalpel, using supersensitive Charged Coupled Devices (CCD) to guide the physician. These are silicon chips that convert light directly into electronic or digital images, making them the heart of fax machines, video cams and a host of telescopes, such as Hubble. A company, working with the Goddard Space Flight Facility, adopted a new CCD for its breast biopsy system to obtain clearer images than conventional x-rays offer. The resulting device images breast tissue more clearly and efficiently than other does existing technologies.

This saves the patient weeks of recovery time and a dollar cost of hundreds of dollars versus thousands for a surgical biopsy. With over half-a-million women needing biopsies every year, the economic benefit is tremendous and it greatly reduces the pain, scarring, radiation exposure, time, and cost associated with conventional biopsies.

Document Monitor

Charge-coupled device technology is also helping to preserve some of America's most treasured documents, including the U.S. Constitution, Declaration of Independence and the Bill of Rights.

That effort began in 1982 when the National Archives asked JPL to develop a systematic method of assessing the condition of historic documents. JPL, in turn, asked the Perkin-Elmer Corporation, of Norwalk, Connecticut, the optical systems prime contractor for Hubble, to apply its expertise to the development of a precise photometer and then to integrate it into a complete document monitoring system. Perkin-Elmer started work in 1984 and, three years later, installed the system at the National Archives. The photometer can detect changes in contrast, shape, or other indicators of degradation with five to ten times the sensitivity of the human eye. Images are captured at precise intervals and compared to previous ones, with special attention to changes in readability due to ink flaking or fading, changes in document dimensions resulting from shrinkage, and enlargement of existing tears and holes.

The National Archives is exploring other uses for the electronic camera, including methods of measuring the effects of conversion treatments on historical documents and authentication of artwork.

Programmable Pacemaker Sets Natural Rhythm

Communications technology that allows clear transmissions between Earth stations and orbiting satellites, also enables doctors to communicate with pacemakers implanted inside the human body.

Bi-directional telemetry, a type of two-way communications developed by NASA, provides the means to both instruct and query the pacemaker. For example, a doctor can send signals to the pacemaker to alter its rate, and also receive signals from the implanted device regarding the status of its interaction with the heart. This way, the doctor can adjust the device to suit a patient's needs as they change over time.

Developed by Siemens-Pacesetter of Sylmar, California, the Synchrony Pacemaker System won Food and Drug Administration approval for general marketing in August 1989, after clinical trials involving more than 750 implants in 90 hospitals. Pacesetter is developing a next generation of pacemakers, to be known as Affinity, in which the number of circuitry components will be halved

yet allow incorporation of automation, expanded data memory and a sophisticated, handheld PC-based programmer. Originally part of Siemens AG, Pacemaker became, in 1994, a division of St. Jude Medical, St. Paul, Minnesota, a leading manufacturer of medical devices for the cardiovascular market.

Implantable Heart Aid

Sudden Cardiac Death (SCD) strikes nearly half a million Americans each year. Eighty percent die before medical help arrives and those who do survive face a two-year recurrence rate, possibly as high as 55 percent.

The Automatic Implantable Cardioverter Defibrillator (AICD), offers new hope with its ability to reduce the two-year SCD mortality rate to less than three percent.

The AICD incorporates space technology-based miniaturized electronics to detect a broad range of spontaneous heart arrhythmias. These include those caused by ventricular fibrillation, during which the heart loses its ability to pump blood, causing death or brain damage in minutes. The AICD works by shocking the heart via electrodes that have been surgically placed in and on the heart. Comprising a pulse generator and two sensors that continuously monitor heart activity, the AICD automatically delivers electrical countershocks to restore a rhythmic heartbeat. It works in the same way as defibrillators used by emergency squads and hospitals, but offers the advantage of being permanently available to patients with high risk of experiencing SCD.

Temper Foam Material

A NASA research program, aimed at improving crash protection for airplane passengers, gave impetus to the development of a cushioning material, that is now used in Space Shuttle seats and many commercial applications.

With the idea of developing a new airline seat to provide better impact protection and comfort during long flights, NASA Ames Research Center developed an open-cell polyurethane-silicon plastic foam. One of its special qualities is that it takes the shape of impressed objects but returns to its original shape even after 90 percent compression.

Commercial application was initially developed by one of the inventors under the name Temper Foam material. Numerous spinoffs of the original technology include orthopedic support cushions used in wheelchairs and other medically-related support applications; use in sports equipment, such as helmets; and even use in the furniture industry as mattresses and cushions.

Advances in Heart Pumps

NASA's expertise in tiny, yet highly reliable, pumps may provide an alternative to the large, external heart pumps used by patients awaiting a heart transplant. Johnson Space Center has combined forces with Baylor College of Medicine, and famed heart surgeon Dr. Michael DeBakey, to make use of the center's expertise in developing the Ventricular Assist Device. This new generation of heart pump is already undergoing implant tests in animals and, if they continue to go well, a first human implant may come soon. These small pumps would allow critical heart patients a much more convenient alternative to those bulky pumps currently in use.

Implantable and External Pumps for Diabetics

Insulin-dependent diabetics have been aided by the use of space technology in the development of both external and implantable insulin delivery systems. A computerized pump can serve as an electronic pancreas to infuse insulin at a pre-programmed rate. This allows for more precise control of blood sugar levels, without which complications such as blindness and kidney disease may result. This frees the diabetic from the burden of daily insulin injections. Both patient and physician can adjust the insulin delivery rate using digital telemetry, a technique developed by NASA to communicate with spacecraft from Earth.

NASA technology also helped create the pumping mechanism, which is based on a design for the biological laboratory of the Mars Viking space probe. The device delivers insulin into the abdominal cavity in short pulses, which conserves battery power. When an insulin refill is needed, about four times a year, it can be injected without surgery by a special hypodermic needle.

A similar device, but worn externally, is the MiniMed 504 Insulin Infusion Pump. Similarly based on NASA technology, the MiniMed SO4 can be clipped to a belt and worn continuously. About the size of a credit card and weighing just 3.8 ounces, it houses a microprocessor, long-life battery, and a syringe reservoir filled with insulin. The syringe is connected to an infusion set that consists of a thin, flexible plastic tube about 30 inches long with a needle at its end. The patient inserts the needle subcutaneously, usually in the abdomen. Insulin is infused at rates determined by the patient's need, as programmed into its microprocessor.

Digital Imaging

Developed in the mid-1960s to explore the surface of the Moon, Digital Imaging - a process that turns analog signals into digital signals which are, in turn, fed into a computer for enhancement - returned sharp, accurate images of the lunar surface. This began a steady stream of advances in digital image processing, spurred by the advent of ever-more sophisticated spacecraft transmitting immense volumes of image data from distances farther and farther from Earth. In the years following, JPL pioneered use of digital processing techniques to enhance electron microscope, x-ray, and light microscope images. Among the medical applications derived from this technology are Computed Aided Tomography (CAT) scanning, diagnostic radiography, brain or cardiac angiography, sonar body imaging, surgery monitoring, and nuclear magnetic resonance.

Infrared Ear Thermometer

JPL expertise with infrared sensors used to measure the birth of stellar nurseries has been applied in ear (aural) thermometers. The infrared thermometer is able to provide an accurate reading in two seconds or less by painlessly placing a hand-held sensor into the ear opening. These are much more comfortable and faster than conventional mercury thermometers.

Laser Angioplasty

Excimer laser technology uses relatively cool ultraviolet light, rather than the heat intensive light of other lasers, to vaporize plaque blockages in coronary arteries without damaging artery walls. The success rate in opening blocked coronary arteries is 85 percent, with fewer complications than in conventional balloon angioplasty. Using this spinoff technology, a company called Spectranetics continues to advance the state of excimer lasers in healthcare.

The main objective of Spectranetics' core laser technology is to reduce obstructive tissue and restore blood flow through minimally-invasive means that are safe, efficient and cost-effective - and/or to facilitate the removal of pacemaker and ICD leads.

Spectranetics' multi-purpose excimer laser system utilizes disposable fiberoptic delivery devices (catheters) to emit ultraviolet light in controlled energy pulses to ablate occlusions.

This technology is widely used to ablate arterial plaque as an alternative or adjunct to other angioplasty procedures and to remove scar tissue which facilitates cardiac lead removal. Spectranetics continually improves its core laser technology with advanced product features.

Because of its success, the Excimer Laser Angioplasty System was honored by the US Space Foundation Space Technology Hall of Fame (<http://ussf.com/hof/>).

Safety

Fabrics

NASA use of aluminized materials to serve as spacecraft insulation, led to a revolution in reflective insulating materials, ranging from survival blankets to wraps for water heaters to new types of home insulation. Extremely strong fire-retarding materials that were developed for use in the pure-oxygen air of early spacecraft have led to a host of fabrics, such as Beta Glass, used in fireproof clothing, accessories and firefighter's suits. Other spacecraft materials have included feather-weight Teflon-coated fibers with great strength, that have been used as roofing material for such structures as the Detroit Silverdome and the Jeddah, Saudi Arabia Airport.

Smoke and Carbon Dioxide Detectors

The technology to develop smoke detectors was first used in Skylab. These early detectors helped eliminate toxic vapors by identifying carbon monoxide and smoke. To distinguish carbon monoxide from water vapor, they removed the water vapor before measurement. Smoke triggered the alarm using an ionization chamber that acted as a sensor. This technology can be found in some of the smoke and carbon dioxide detectors available today – which has helped decrease deaths from house fires in America by one-third, since 1977.

Radiation-Blocking Lenses

Taking a tip from nature, and a technology spinoff from NASA, Suntiger Biomedical optics (<http://www.suntigers.com/>) in North Hollywood, California, produced a line of sunlight-filtering glasses that protect human vision by blocking blue, violet and ultraviolet light. Research has shown these can cause eye disorders such as cataracts and senile macular degeneration. The Suntiger PST (Polarized Selective Transmission) lenses stylishly filter out 99 percent of these potentially harmful wavelengths.

Space Technology Helps Firefighters

The same technology that releases a Space Shuttle orbiter from its giant fuel tank - by exploding huge fasteners - has been incorporated into cutters that firefighters use to free crash victims from

smashed cars. Explosive power cartridges are the secret of Life-Shear cutters - lightweight, portable emergency rescue cutters for situations where saving seconds means saving lives

Firefighters, like astronauts, often brave dangerous, hostile environments protected by the technology on their backs. A variety of technologies first developed for space exploration, have turned into notable fire fighting and prevention spinoffs. These include a portable fire fighting module, protective clothing for workers in hazardous environments, fire-retardant paints and foams, fire-blocking coatings for outdoor structures, and flame-resistant fabrics. Perhaps the most noticed is the breathing apparatus worn by firefighters throughout the world for protection from smoke inhalation injury.

In 1971, in response to concerns expressed by many of the nation's fire chiefs, NASA began the first concerted effort to improve firefighter breathing systems, which had not changed appreciably since the 1940s. The traditional breathing system was cumbersome, and so physically taxing that it often induced extreme fatigue. Many firefighters decided not to use the equipment, electing to brave the smoke rather than risk collapse from heat and exhaustion. As a result, smoke inhalation injuries increased.

In concert with the National Bureau of Standards - Fire Technology Division, NASA established a public interest project directed by Johnson Space Center (JSC). JSC embarked on a four-year development effort that applied technology from the portable life support systems Apollo astronauts used on the moon. In the resulting spinoff, Martin Marietta Corporation and Structural Composites Industries were awarded contracts to build lightweight air cylinders patterned on technology originally developed for rocket motor casings. Scott Aviation received the contract to build the remaining components. The resulting breathing system weighed only 20 pounds, one-third less than past systems, and improved wearer mobility. It consisted of a face mask, frame and harness, a warning device and an aluminum-composite air bottle capable of holding twice the amount of air.

Use of the lightweight apparatus spread quickly across the country. The result has been a drastic reduction in the number of inhalation injuries to firefighters.

Food Processing Control

The Pillsbury Company of Minneapolis, developed the Hazard Analysis and Critical Control Point concept, designed to prevent food safety problems. They used NASA space technology to do it.

When NASA started planning for manned space travel back in 1959, myriad challenges of sustaining life in space included figuring out what to feed an astronaut. The main concerns involved safety - preventing food crumbs from contaminating the spacecraft atmosphere or floating into sensitive instruments, and assuring freedom from disease-producing bacteria, viruses and toxins. To solve these problems, NASA enlisted the help of Pillsbury. Over the next decade, Pillsbury designed some of the first space foods and produced astronaut meals for the Mercury, Gemini, and Apollo manned spaceflight programs. Pillsbury quickly solved the crumb prevention problem by coating bite-size foods to prevent crumbling.

Insuring against bacterial contamination proved a more difficult task. Investigators found that simple standard quality control methods were not enough. Answering the challenge, Pillsbury developed an overarching system for quality assurance, the Hazard Analysis and Critical Control

Point (HACCP) concept to prevent food safety problems. It is potentially one of the farthest-reaching space spinoffs.

Within two years of the first lunar landing in 1969, Pillsbury plants were following HACCP procedures in production of food for Earth-bound consumers. Pillsbury's subsequent training courses for Food and Drug Administration (FDA) personnel led to the incorporation of HACCP in FDA Regulations.

HACCP has grown into a pro-active, internationally recognized process control system which ensures food quality. This system has been adopted around the world and is mandatory in some countries. The HACCP process consists of: Hazard Analysis, Identifying Critical Control Points (CCP), Establishing Critical Limits for each CCP, Monitoring CCP requirements and using the data gathered to effectively control processes, Corrective Action, Record Keeping, and Verification.

TRANSPORTATION & POWER SOURCES

Windshear Prediction

Space has made air travel faster, safer and more affordable. Dozens of design advances have been made to airplanes as a result of space research. One led to the development of a device that predicts windshear - a dangerous and invisible weather condition that can cause airliners to crash. This Doppler radar system has the ability to give pilots 20-40 seconds warning about upcoming windshear, giving them time to avoid it.

Neural Net Chip

Ford Motor Co. signed a licensing agreement with JPL for use of neural net technology to diagnose misfiring under the hoods of Ford automobiles, among many potential applications. The vehicle applications will mean that artificial neural networks will learn how to diagnose problems, such as engine misfires and to control the engine to optimize fuel economy and emissions.

Photovoltaic Solar Energy

When sunlight strikes certain materials, such as silicon, electrons are set in motion. These mobile electrons can be drawn off as electricity. This basic principle of photovoltaic conversion, or PV, is used to provide power to nearly all man-made satellites. NASA pioneered PV power for spacecraft and has supported U.S. Department of Energy programs to expand Earth applications. NASA's Jet Propulsion Laboratory is the group primarily responsible for developing advanced PV technology while cutting its costs.

PV power has proven a viable alternative energy source in areas where no conventional source exists, such as remote automated weather stations, sea-based navigational buoys, forest stations, and third world villages. PV arrays are routinely used at remote communications installations to operate large microwave repeaters, TV and radio repeaters, rural telephones, and small telemetry systems that monitor environmental conditions.

Terrain Collision Avoidance System

Synthesis of digital maps and GPS data, using NASA expertise in synthetic aperture radar, has been applied in a terrain-mapping program for small aircraft. Dubbs & Severino, a small business located in Southern California has developed terrain collision avoidance software that continuously displays an 8 minute safety zone with local terrain information in any weather. Their system runs on a battery-powered laptop in the cockpit of small aircraft for one-tenth the cost of comparable systems.

Software for Safer Skies and Earth Monitoring

During the 1980s The Jet Propulsion Laboratory, NASA and other research centers began to work toward developing a capability for precise positioning using Global Positioning System (GPS). This led to a spinoff technology known as GIPSY-OASIS. GIPSY stands for GPS-Inferred Positioning System. OASIS is an acronym for Orbit Analysis and Simulation Software. This system is now in worldwide use to generate the most accurate GPS positioning solutions ever achieved.

Recent enhancements enabled scientists to precisely estimate changes in ocean height, helping lead to better predictions of oncoming storms wrought by El Nino. The El Nino and La Nina events affect millions of people and billions of dollars globally.

Raytheon has developed a commercial spinoff of a real time version of this system for implementation into the FAA Wide Area Augmentation System (WAAS), which will provide all commercial airliners in U.S. airspace with accurate real-time knowledge of their position. WAAS has the potential to save billions of dollars in fuel and flight costs, while greatly enhancing aviation safety for millions of travelers.

GIPSY is also used with the Southern California Integrated GPS Network array to record millimeter-scale slips on faults and monitor the strain accumulation in Southern California's crust. Understanding of area seismic activity could lead to a better grasp of the mechanics of earthquakes and to better assessment of the damage they might do.

This NASA developed technology is made available at no cost for scientific research uses. Through licensing programs, it has moved from into the U.S. private sector, for use by companies such as Raytheon, Lockheed-Martin, TRW, Orbital Sciences, Stanford Telecommunications, Computer Sciences, Illgen Simulations and Ball Aerospace.

Ephemerides Data

Navigating the solar system requires planetary and lunar ephemerides of the highest possible accuracy. These are tabular measurements of the assigned places of celestial bodies in space. JPL planetary orbital calculation formulas are now available both by web (<http://ssd.jpl.nasa.gov/>) and CD-ROM. The CD-ROM version is ideal for backyard astronomers who can't easily download huge amounts of data. Most of the world's almanacs are based on the JPL ephemeris data. Historians and archeologists use ephemerides for the dating of key events. Other users of ephemerides include surveyors, the Department of Defense, weather forecasters, consulting firms, and satellite manufacturers.

Environment

Safeguarding the Harbor Porpoise

To help protect the, a low-cost, easy-to-use acoustical pinger stands to gain wide acceptance in the fishing industry. For decades, Harbor Porpoises have been killed during commercial fishing operations. These air breathing mammals are trapped and drown in sink gill nets, which are commercial fishing devices meant to catch bottom-dwelling fish in shallow waters.

Taking on the challenge of lessening the accidental death of Harbor Porpoises, the Dukane Corporation Seacom Division, in St. Charles, Illinois designed the NetMark 1000 system. This unit emits signals that warn Dolphins of a net's presence.
(<http://www.dukane.com/seacom/default.htm>)

The NetMark 1000 employs technology originally developed in the late 1960s by NASA engineers at the Langley Research Center. At that time, an underwater location aid, able to withstand high impact, was crafted to emit multidirectional signals for hours on end. Its key purpose was for use in the retrieval of NASA payloads following watery splashdowns on Earth.

Dukane Corporation and Burnett Electronics of San Diego, California obtained a license from NASA, further improving on the beacon design. Dukane has sold well over 100,000 units to scare Harbor Porpoises away from deadly nets and much more. The variety of applications for Dukane pingers includes attachment to black box flight recorders on commercial airliners, marking underwater sites and relics, plus helping to ensure recovery of hazardous cargo in case of loss.

Alaska Pipeline Heat Pipes and Sensors

NASA heat pipe technology plays a vital role in protecting the Alaskan environment from possible pipeline oil spills. The Alaska pipeline is also looking at chemical sensors to provide monitoring ability for the pipeline to detect leaks and oil releases below the present leak detection threshold. New technologies may also help the company find leaks more quickly.

Automated Credit Exchange

A commercial spinoff developed by Sholtz & Associates, Pasadena, California, is an electronic-bartering software. Originally the system was designed to manage the development of scientific instruments on the Cassini spacecraft on its mission to explore Saturn. Today it is helping the Southern California Air Quality Management District manage air pollution credits in a more effective way.

Small Inner-City Business

Displaymor, a woman-owned small-business in South Central Los Angeles, faced new Food and Drug Administration requirements for lower operating temperatures of their company's refrigeration showcase products. She needed to lower her refrigerator temperature two degrees. By working with JPL engineers, who were experienced in the thermal requirements of spacecraft, they were able to redesign Displaymor's refrigeration units with space technology developed insulation to meet the new requirements from the FDA.

Education

IMAX Films

IMAX big screen cameras have been carried on numerous shuttle missions, and scores of astronauts have been trained to operate them. NASA generated computer-enhanced images of the Earth have been used to simulate fly-bys of such areas as the San Andreas fault in California. IMAX films about the space program, have been seen by millions of people around the world. A current project for IMAX is a 3D Mars movie on future robotic outposts on the Red Planet.

Ecosphere Miniature World

Models of a miniature world in an enclosed glass globe helps students understand environmental systems. The first EcoSphere globe was modeled on an experiment by JPL scientists studying self-contained communities for space explorers to live in during long-term flights.

National Geographic Global Satellite Map

On its hundredth anniversary the National Geographic Society made a special gift to the nation. It established an Education Foundation and endowed it with an outright gift of 20 million dollars. The earnings of the endowment were forever dedicated to improving the geographic literacy of American students by providing a permanent and expanding source of financial support for exemplary geography education programs. Their mission is to revitalize the teaching and learning of geography in the nation's K-12 classrooms.

As one of the world's largest non-profit scientific and educational entities, this Foundation worked with the JPL Cartographic Division to update a satellite imaged map. They then marked the new millennium with a gift to America's children. Each of the nation's more than 100,000 public and private schools received a 4-by-6 foot laminated, updated map of the world. One side shows the political world. The other side is a digital picture of the physical world based on images collected by with NASA satellite technology.

=====